For the circuit above, $V_i = 10 \text{ mV}$:

- What is $V_o$ if the amplifier is ideal?
- What is $V_o$ if the offset voltage, $V_{OS} = 10 \mu \text{V}$?
- What is $V_o$ if the bias current, $I_B = 10 \text{ nA}$?

- What is $V_o$ if the amplifier is ideal?
  
  Represent ideal as $\bar{V}_o$

  \[
  V_+ = \frac{22 \text{k} \Omega}{22 + 2.8 \text{k} \Omega} V_i = (8.870 \text{ mV}), \quad \bar{V}_o = \left(1 + \frac{22 \text{k} \Omega}{2.8 \text{k} \Omega}\right) V_+ = 8.857 V_+ = 78.562 \text{ mV}
  \]

- What is $V_o$ if the offset voltage, $V_{OS} = 10 \mu \text{V}$?
  
  Use superposition to get $(V_o')$ then add to ideal $V_{OS}$:

  \[
  V_o' = \left(1 + \frac{22 \text{k} \Omega}{2.8 \text{k} \Omega}\right) V_{OS} = 8.857 \times V_{OS} = 0.089 \text{ mV}
  \]

  \[
  V_o = \bar{V}_o + V_o' = 78.651 \text{ mV}
  \]

- What is $V_o$ if the bias current, $I_B = 10 \text{ nA}$?
  
  First, use superposition to get $(V_o')$ for $I_B$ into $V_+$. Current travels through parallel resistors.

  \[
  V_o' = - \left(1 + \frac{22 \text{k} \Omega}{2.8 \text{k} \Omega}\right) (R_1 \parallel R_2) I_B = -8.857 \times 2.484 \text{k} \Omega \times I_B = -0.220 \text{ mV}
  \]

  Next, use superposition to get $(V_o'')$ for $I_B$ into $V_-$. Current through $R_1$, since FB keeps $V_-$ at ground. Note that this resistor configuration cancels $I_B$.

  \[
  V_o'' = (22 \text{k} \Omega) I_B = 0.220 \text{ mV}
  \]

  \[
  V_o = \bar{V}_o + V_o' + V_o'' = 78.562 \text{ mV}
  \]
The op amp is ideal, except $f_T (=\text{Gain\text{-}Bandwidth})$ is 120 kHz.

For the circuit above, $V_i = (20 \text{ mV}) \cos(2\pi ft)$:

- What is the peak-to-peak amplitude of $V_o$ if $f = 3 \text{ kHz}$?
- What is the peak-to-peak amplitude of $V_o$ if $f = 30 \text{ kHz}$?

First, analyse ideal gain, $\bar{V}_o$

\[
V_+ = \frac{25 \text{ k}\Omega}{25 + 3.9 \text{ k}\Omega} V_i = 0.865 V_i \quad \bar{V}_o = \left(1 + \frac{25 \text{ k}\Omega}{3.9 \text{ k}\Omega}\right) V_+ = 7.410 V_+ = 6.410 V_i
\]

- What is the peak-to-peak amplitude of $V_o$ if $f = 3 \text{ kHz}$?
  Given Gain-Bandwidth, maximum possible gain is $G = (G \cdot BW)/f = 120/3 = 40$.
  We specify a gain of 6.410 which is less than 40, so we get the specified gain.
  $V_o = 6.410 \times (20 \text{ mV}) \cos(2\pi ft)$, and peak-peak voltage is $2 \times max(V_o)$.
  Answer: 256.4 mV.

- What is the peak-to-peak amplitude of $V_o$ if $f = 30 \text{ kHz}$?
  Given Gain-Bandwidth, maximum possible gain is $G = (G \cdot BW)/f = 120/30 = 4$.
  We specify a gain of 6.410 which is greater than 4, so we only get a gain of 4.
  $V_o = 4 \times (20 \text{ mV}) \cos(2\pi ft)$, and peak-peak voltage is $2 \times max(V_o)$.
  Answer: 160.0 mV.
For the circuit above:

- **What type of filter is this?** (high pass, low pass, band pass, band stop)
  - This is a low pass filter

- What is the cut-off frequency \( f_c \) and damping constant \( \zeta \)?
  \[
  \omega_c = \frac{1}{\sqrt{LC}} = \frac{1}{\sqrt{4.9 \, \text{mH} \cdot 19.4 \, \mu\text{F}}} = 3243.404 \, \text{rad/s}, \quad f_c = 2\pi \omega_c = 20378.482 \, \text{Hz}
  \]
  and,
  \[
  \zeta = \frac{R}{2} \sqrt{\frac{C}{L}} = \frac{248 \, \text{k}\Omega}{2} \sqrt{\frac{19.4 \, \mu\text{F}}{4.9 \, \text{mH}}} = 7.802
  \]

- Sketch the amplitude of \( \frac{V_o}{V_i} \) as a function of frequency. Label the passband, stopband and roll-off rate.
  \( \frac{V_o}{V_i} \) starts near 1.0. After \( f_c \), graph decreases at 40 dB/decade.